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The challenges of energy efficiency innovations in the Nordic building sector

Greener Markets and Cleaner Technologies (GMCT)

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Nordic cooperation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and three autonomous areas: the Faroe Islands, Greenland, and Åland.

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Nordic cooperation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

Content

Preface

The Green Markets and Cleaner Technology project targeted the environmental innovation issue. The areas has been highlighted in recent years, not least in the Nordic countries, as one important path for sustainable growth and simultaneously make use of the developments and the gained knowledgebase that has followed a stringent environmental policy. In essence it demonstrates the need of combining the policy areas of innovation, economic growth and environmental protection. This GMCT project is one of an array of different approaches within the field but with the specific focus on environmental performance of products and processes related to common products and sectors that primarily don't operate in the traditional environmental technology area. The aim of the project has been to learn from real cases, successful innovations in existing companies, in sectors where the Nordic industry has a strong environmental position order to analyze the innovation system. The closely studied sectors are pulp and paper, mobile phones and buidings. Ultimately, the results should be possible to extrapolate and translate in policy recommendations that could strengthen both the studied sectors per se and the development of emerging environmental technologies, such as biotech, nano-technology, micro electronics, etc. We believe that not least the analytical model for understanding opportunities for policy intervention in the innovation system could be a useful tool for future actions and the interplay between innovation and environmental policy. Currently, it seems like that connection and coordination is weak.

This report describes the innovation system in the Nordic building sector and is the summary of findings from investigations conducted in 2005–2007. Far from all details have been included in this report – much of the background work has been reported in two theses, a handful of articles and conference presentation and one Nordic building sector workshop. Thus, there is much more to digest for the eager reader.

The GMCT project is truly Nordic and has been conducted in co-operation with Risø National Laboratories and Department of Development and Planning, Aalborg Uninversity, Denmark, the Finnish Environment Institute SYKE, Finland and the International Institute for Industrial Environmental Economics IIIEE at Lund University. The latter has also been the leading part and responsible for this report. We would like to thank all partners and, of course, the Nordic Council of Ministers who has financed and commissioned the project for great co-operation and mutual support.

Furthermore, our gratitude to Vida Rozite and Morrigan Heyes, our two devoted MSc students who have, through their theses, contributed

substantially to the process and to Bernadett Kiss, who helped out with a number of practical issues. Not least, we owe all industry representatives and practitioners that kindly supported us with necessary information and participation in meetings and the workshop a great thank you all.

Finally, we have learned a lot about innovation systems from this process of working with practitioners and firms. It as been very fruitful, inspiring and brought about good experiences. Thus, we hope that the outcomes will reach people involved in innovation in one of other way and that they will find it useful in their work.

Lund, 10th of March 2008.

The Authors

Summary

In this report we provide a summary of the results from the investigation into cases of energy efficiency innovations in the Nordic building sector as a part of the Green Markets and Cleaner Technologies (GMCT) project. The GMCT project was financed by the integrated product policy group of the Nordic Council of Ministers and carried out in cooperation with the Finnish Environmental Institute, the University of Aalborg and Risø National Laboratory at the Technical University of Denmark.

The aim of this sector study is to provide empirical materials for the GMCT project on the processes and system conditions that facilitate or hinder environmental innovation in sectoral contexts, in this case the building industry context. It is based on literature review, two master thesis projects conducted in the context of this project, interviews, workshop discussions and comments from representatives of the Nordic building industry. The cases investigated are mainly from upstream material and component suppliers in the building value chain. They include cases of incremental improvements on existing products, to new products and product systems.

The review carried out in this report regarding the industry context highlights several important features of the construction industry with significant implications on the innovation environment in buildings. The most important feature is the project-based nature of the industry and where adoption of innovation takes place in projects not in firms. The second aspect of this environment is the large number of actors involved in the decision making process, where the actions of one party ultimately affect the actions of the next. As such, the production of a more energy efficient building is the result of complex and combined efforts from a series of actors. Not only must the building owner be willing to finance the more energy efficient building, but the building and its systems must be properly designed by the architects and engineers and the necessary people with the correct skills must be available to complete the construction. Additionally, the compartmentalization and divisions within the building value chain, the differences in 'adsorptive capacity' for knowledge integration among the actors involved in building projects, and the cyclical nature of the sector which affects investments in new knowledge; are also quite evident features of this sector.

These features of the construction work, though not unique to Nordic markets, create a constraining environment for innovation in general and energy efficiency in particular. For instance, new knowledge that is gained during a building project as a result of various interactions and learning processes may be difficult to capture and/or transfer to future

projects. Different constellations of actors may work together on different projects, resulting in difficulties in collecting experiences. Furthermore, as the actors involved come from a variety of backgrounds, their experiences may be largely restrained to their particular sector of specialisation. Given these conditions, how do successful energy innovations make it to the mainstream market? And what insights can we gain from the innovation behaviour of the actors in real cases? These are some of the questions we tried to explore by looking at specific cases found on the Nordic building markets.

Findings from the cases point to several strategies deployed by innovating companies to overcome some of the constraints highlighted above. On the issue of coupling of actors; open standards, product certifications, and complementary communication tools played an important role in lubricating the flow of information and creating legitimacy to new modification. Case companies' use of demonstration projects and performance guarantees seem to have addressed the skepticism about the innovation itself and created a cycle of learning about the integration at the project level. Transfer of project level learning to familiar routines among the actors network, remains a risky business that deters from wide adoption. A focus on simplicity, ease of installations complemented with stable alliances, training, and easy coupling of actors, evident from the case companies, seem to have played a role to ease the risk perception.

Following this, we also looked at the enabling and constraining conditions in three activities of an innovation system (access to knowledge, access to resources and market formation) and how they influence the propensity for energy efficiency innovations.

In the area of knowledge, and looking specifically at upstream actors such as materials suppliers, building services systems producers, engineers, and designers, there is a high degree of 'adsorptive capacity' with regard to identification and utilization of new knowledge that is important for innovation. This is due in part perhaps to some of the features found in Nordic innovation systems such as strong knowledge base in complementary areas of material sciences, mechanical engineering, design and electronics coupled with highly trained labor force in most segments of the industry. On the other hand weak relationships with formal knowledge institutions such as research centers and universities have been cited on several occasions. Another fundamental weakness is the absence of energy efficiency learning from the traditional training of designers, engineers and consultants. Although one could find specialized courses on climatic design, passive buildings, alternative heating and cooling technologies as examples, these tend to remain outside the traditional specializations accessible to building sector.

In the provision of resources, the sector faces several issues. These tend to affect innovation in general and not particular to energy efficiency. On the human resources side, the sector is facing an ageing skilled labor force coupled with lack of interest from younger generations. However this issue seems to have been noted by educational policy makers in some of the Nordic markets in particular Sweden where new programs have been launched to make it attractive for young graduates to enter into this sector. The cyclical nature of the building market in Nordic countries seems to have also impacted investments in development activities. The upswings and downswings is said to have an effect on the industry's access to financial and human resources, acting as a barrier to investment in research activities.

With regards to *market formation*, in most Nordic markets building codes are claimed to be most influential instruments for creating the demand for energy efficiency in buildings. The effect however has been limited to certain areas of applications, mainly insulations and heat recovery. This and a historic emphasis on technical specifications (u-values of wall materials) rather than performance specifications (end energy demand per functional units) led to incremental improvements rather than radical changes. The split-incentives in energy investments (one party pays for the investments and another party pays for the energy bill) has also been noted as a market barrier, but this is not unique to Nordic markets and pervasive across the sector internationally. There could have been an opportunity to overcome this split-incentive issue in the Nordic market with the strong role of municipal housing firms to steer the market differently considering the 'public good' nature of their work.

Finally on the role of public policies, there is a need for high sensitivity to the specific features of the dynamics of interactions in the sector. Despite the fact that we can identify many possible ways of boosting energy efficiency in buildings, adoption at the project level is complicated by systematic and structural features in the building innovation system. This has direct implications on policies aimed at achieving transformation towards a more energy efficient building stock. In this context, the commonly used tool box of tax incentives and subsidies for energy efficiency measures has proven to be of limited success. We conclude that an emphasis is needed more on measures that actively reduce the uncertainty associated with experimentation from project level adoption and facilitate learning, knowledge and information flows in a sector characterised by its fragmented knowledge base.

1. Introduction

The building sector is considered an important arena for environmental action because of the scale of impacts. World wide, the built environment direct and indirect contribution to environmental impacts is estimated in the range of 30% to 40 % of total impacts (UNEP 2007). Energy efficiency is one focus area because of its potential to bring substantial improvements. In the European Union, energy used in the built environment constitutes 40% of the total energy consumption (UNEP 2007). Hence changes in the built environment in the form of solutions and measures promoting energy efficiency provide the largest single potential for reducing the total energy consumption (EC Green Paper on Energy Efficiency 2005). According to the *EC Directive on the energy performance of buildings* an estimated 40 Mtoe could be saved by year 2020, corresponding to almost a fifth of the European Kyoto Protocol targets (Jansen 2004, EC Directive on the energy performance of buildings 2002). In Nordic countries, the potential in improving the energy performance of the building sector has been highlighted in countless policy documents. Another aspect of interest for this project is also the perceived potential of the sector to be a driver for the development of cleaner technologies with its cross over to other knowledge clusters within Nordic manufacturing such as materials, mechanical industry and automation.

Related to this, evidence suggests that there is wide range of energy efficiency solutions available to the Nordic construction industry. These range from simple design changes to technologically advanced solutions. The Nordic landscape is full of successful demonstration projects literally demonstrating the entire range of all these possibilities. At issue here is why we do not see wide spread diffusion of these innovations in buildings despite all the demonstration projects and policy support for energy efficiency?

This question is neither new nor strange to the literature on energy efficiency and buildings. There is a large body of empirical material on the subject looking at the problem from a variety of perspectives beyond just price rationality to economic sociology (Biggart and Lutzenhister 2007) and the social structuring of technical innovations (Shove 1998). In this project we attempt to add a more nuanced understanding of the problem of energy efficiency in building through closer examination of the dynamics of innovation and adoption across different activities within the building construction system. For this, we use innovations system perspective as an analytical framework. The innovation system perspective posits that innovation is embedded in networks of organizations, people and institutions within which the creation, diffusion and commercial exploitation of new technologies and other types of knowledge takes place (OECD 1997). The advantages in taking this perspective is that it helps us to better understand the dynamics of interactions among different actors in the innovation process and how policy should be sensitive to these dynamics if greater diffusion of ideas is warranted.

In this report, we briefly review the sectoral features found in the innovation system of the building sector. This provides us with the platform and the constraints under which energy saving techniques are introduced. We then investigate three types of energy efficiency innovations derived from about 20 candiadates[1] and the firms' strategies under such constraints. The findings are then discussed in relation to policy stimuli to address constraining features found in the Nordic building sector along three main activities within an innovation system; these are 1. access to knowledge, 2. access to resources, and 3. formation of markets.

[1] Reported in Rozite 2006.

2. Analytical Framework

There has been an increase in the general understanding of innovation processes with strong evidence to the dynamic nature of innovation. Dynamic models based on the systems perspective capture many of the challenges connected to the process of change and provide a framework from which to examine the role of institutions and the behaviour of various actors and their interactions (Edquist 1997). It thus allows for the identification of opportunities, and also barriers that need to be addressed. Furthermore, we have also better understanding with regards to the differences in the organization of innovation activities across industrial sectors (Malerba 2005). It is this general knowledge of innovation dynamics in national and sector systems which constitute the analytical basis for this paper. Of particular interest here is the sector level of innovation systems.

A sector can be defined as a set of actors that are unified by related product groups or technologies for an existing or emerging demand and which share a basic knowledge base. Thus, *sectoral systems of innovation* share a knowledge base, technologies, inputs, demand and are comprised of actors that carry out market and non-market interactions aimed at creating, developing and diffusing new products within a given sector (Malerba 2005). Within the field of innovation studies, it has been widely recognized that the sectoral features of a particular industrial sector play a significant role in influencing the innovation process (Reichstein, Salter et al. 2005).

A useful way to analyse the working of an innovation system is to focus on how a number of functions are served in the system (Jacobsson and Bergek 2004). The innovation system literature suggests various levels of categorizations of these functions (e.g. Chaminade and Edquist, 2006). Crucial activities that can be ellusidated from the literature are the creation, the pooling and the transfer of knowledge, the access to resources and the formation of markets. These can be detailed to more specific activities depending on the unit of analysis; technology system or territorial system. By arranging our findings in terms of these activities, we can trace the way through which, for instance, a particular combination of actors or specific institutional set-up shapes the generation, diffusion and utilization of energy efficicency innovations.

3. The Innovation System in the Nordic Building Sector

3.1 Sectoral Features and Innovation Influences

It is widely recognised that the building sector differs from other industry sectors with regard to innovation due to characteristics inherent to the construction work. These characteristics are found in the industry in general and they are not necessarily specific to the Nordic markets. The most prominent feature of the industry with implications to innovation diffusion is its project-based orientation as opposed to a process orientation (Taylor and Levitt 2005). This means that different firms enter into temporary collations and collaborate on constructing specific projects every time. After the project is finished, the coalition is loosened. This unique feature has particular implications for our discussion on environmental innovation. Because innovation adoption takes place in projects, not firms, most innovations have to be negotiated with one or more of the actors in these temporary collations.

The project-based structure creates several constraints for effective learning and transfer of knowledge, necessary for innovation. The knowledge encompassed in a building project is both tacit and codified, with a large amount of knowledge gained during the actual building process that rarely are documented or transformed into organisational learning. It has been suggested that tacit knowledge may be particularly important in the building sector (Gann and Salter 2000). However, the tacit-based knowledge combined with the project-based nature of the industry has been noted as a potential source of weakness for innovation process. New knowledge that is gained during a building project as a result of various interactions and learning processes may be difficult to capture and/or be transferred to future projects. A cooperation based on temporary contracts between changing configurations of actors makes the learning process more difficult and slows down innovation (Goverse et al. 2001). This is exemplified in the divisions between various actors in the building chain. Building materials suppliers are often not involved in the design or building process and the design phase is often separated from the construction phase. As such, lessons learned in one system area often do not get passed on to another.

In addition to the project-based structure, other features of building sector pertaining to innovation are the involvement of wide range of actors and the nature of the product. A building "project" requires engagement of a wide range of actors such as building material companies, engineers, architects, building developers and construction companies. Buildings are comparably expensive products with a long life-time. An issue often discussed in this regard is the inappropriate allocation of risks and benefits (Widén 2002). Due to the high price of the product, the building industry typically strives to reduce risk and ensure reliable economic returns on investments by the use of standardised approaches and models that have previously been effective, instead of striving to integrate innovative approaches. Furthermore, the distribution of technological risks and financial rewards is unbalanced, since financial reward of success travels upwards towards client (end-users) and risk of failure downwards in the supply chain (investors on technology). Another dimension of this problem is end-users' focus on lower initial price rather than on performance. A high initial cost of the house they are purchasing, together with lack of direct contact with end-users and the actors who have capacity to apply innovative solution, often leads to end-users' unwillingness to pay more for energy efficiency. This in turn adds to developers' hesitance to apply new technologies.

In addition, as the actors involved come from a variety of backgrounds, their experiences may be largely restrained to their particular sector of specialization. This may further hinder the effective pool and transfer of knowledge.

Thus a main conclusion from the literature on innovations in buildings is that the features of the construction work create constraining conditions for innovations in buildings. This affects not only the diffusion of energy efficiency innovations in particular but all types of innovations.

3.2 Characteristics of the Nordic Building Sector

The building sector plays a significant role in the Nordic national economies. The building and construction industry employs a substantial number of individuals; ranges from 6% to 8% of the total labour force (Ingvaldsen, Lakka et al., 2004). The contribution of the sector to GNP is also substantial. For instance, in Norway, the turnover of the sector is estimated at around 20% of the Norwegian GNP (Enova 2007). In the following we look into some more detailed features of the Nordic building markets.

3.2.1 The role of the state

The Nordic markets share several features with regard to the housing sector. First is a history of state intervention in the residential segment, through commissioning of buildings, rent controls and subsidies for both construction companies and households. Sweden has been the leader in these aspects with strong interventionist housing policies. During the 1950s–1990s a system of subsidies and tax breaks were in place to stimulate the sector, however, these were almost completely withdrawn in the 1990s. Despite this, the sector is still to a large degree state managed through controls, constraints and other policy initiatives. In Denmark, local and central governments guarantee loans and provide capital subsidies for building and improvements. However, the scale of public subsidies has decreased in recent years. Housing benefits are available and approximately a fifth of all households receive benefits (RICS 2005). In Finland a subsidy policy was set up in the 1990s for housing companies after a severe slump to encourage building and renovation. Second is history of severe swings in construction activities, where currently nearly all Nordic markets are experiencing an upturn in construction activities after severe slump in the early 1990s (RICS 2005). This has been noted by several actors in the industry to cause negative implications on the innovation environment of the building sector (Sector Workshop 2007).

3.2.2 Dwellings and ownership patterns

With regard to dwelling types and ownership patterns, the landscape is slightly more varied. Sweden and Denmark have a comparatively higher percentage of households living in rented or co-operatively owned apartments in multi story buildings. In Sweden in particular a great proportion of the multi story buildings were commissioned by municipal or public housing companies in effect giving these companies a strong role in Swedish housing policy (RICS 2005). While in Norway and Finland, a higher proportion of the stock is made up of privately owned single-family homes. Another noted difference is in Denmark, where building costs are comparatively 20 – 30 % higher for single family homes than the costs for corresponding properties in Sweden and Finland (RICS 2005).

3.2.3 Industry actors

As for industry actors, large developers play a significant role in the Nordic markets. Developer represents the actor in the project with the financial resources. Consequently, they execute the major economic decisions and issue the primary demands regarding the building's construction. Within Sweden there are currently three major players in the building construction arena, who display similar prominence in the construction industries of other Nordic countries. These large contractors are also active as building developers and it has been noted that there seems to be an increasing trend in all Nordic countries that the contractor and the developer are part of the same company or trust *(Ingvaldsen, Lakka et al. 2004)*. A similar domination of the building market by a few large firms has also been noted in Denmark, Norway and Finland *(Ingvaldsen, Lakka et al. 2004; Virtual Finland 2004; Kristiansen, Emmitt et al. 2005; Rozite 2006)*.

In terms of building material producers, in most cases, a few producers of a given material lay claim to 80–100% of the market (Ingvaldsen, Lakka et al. 2004). Furthermore, it has been noted that in certain areas within Sweden, including aggregates, prefabricated concrete elements, asphalt, ready made concrete and concrete pipes that many producers are, in turn, owned by the large contracting firms (Ingvaldsen, Lakka et al., 2004). Similarly, within Denmark, some of the largest contractors have purchased installation firms, building material firms and other trade firms, increasing their own size and moving towards control of a larger portion of the value chain (Kristiansen, Emmitt et al. 2005). This indicating a general shift towards vertical integration within the construction sector. Within both Sweden and Denmark, the construction sector has faced criticism regarding lack of competition (Ingvaldsen, Lakka et al. 2004; Kristiansen, Emmitt et al. 2005).

In the area of building service installation firms (typically subcontractors), who are responsible for the supply and installation of heating, ventilation, water supply and drainage units, the market is more varied. It is characterized by a few large and many small firms (Ingvaldsen, Lakka et al. 2004; Reichstein, Salter et al. 2005). The renovation and home repair business is, likewise, dominated by many small firms (Brown, Southworth et al. 2005).

While efforts have been made in recent years to create more formal linkages with the construction industry, historically the relationship between the construction industry and government has been a less collaborative and more distant one. Furthermore, it has been noted that university and research institute linkages are weak in many cases, outside of those that typically exist with the largest firms (Brochner 2006; Rozite 2006).

3.2.4 Policies and regulations

In the building sector, the Building Code has often been cited as one of the most significant components in influencing energy efficiency improvements in the building sector. In the Swedish context, the first concerns regarding energy efficiency appeared in the national building code in 1960 (Smeds 2004) with component specific U-values and requirements for double pane windows. The energy efficiency demands of the code were significantly strengthened following the oil crisis in 1977 and several efforts to further tighten the demands of the code have been made since (Smeds 2004). Similarly in Denmark, the energy efficiency demands of the code have been progressively tightened over the last several decades. Further tightening of the codes is anticipated for 2010 and for 2015 (Rockwool, 2007). In some instances, the code has been criticized for restricting innovation possibilities and for flaws or weaknesses in its efforts to mandate energy efficiency measures (Smeds, 2004). Regardless of these criticisms, however, based on interviews and review materials there is an apparent agreement among a number of stakeholders that the building code is an important tool in the building industry.

In 2003, the EU Directive on the Energy Performance of Buildings (EPBD) entered into force, reinforcing the effort to incorporate energy efficiency into building requirements. This framework directive, stipulates among others that a certification system be developed for buildings that will make the energy consumption levels much more readily apparent to all parties (European Commission 2003). All Nordic countries are currently implementing the EPBD.

In addition to the building code and energy performance directive, a number of other policies, including energy taxes, energy saving information and advice programmes, and investment and subsidy schemes have been used to help effectuate positive changes in the area of energy efficiency in buildings. A number of evaluations have been performed regarding various policy instruments aimed at promoting energy efficiency, though these evaluations often focus on effectiveness and efficiency of the adopted measures, rather than their innovation fostering effects. Several studies, which have focused on the innovation aspect of such energy efficiency policies have largely served to confirm the notion that existing policies have had very moderate effects on innovation, typically resulting in incremental innovations in existing products and diffusion of existing technology (Kemp 1997; Beerepoot 2007).

3.2.5 Energy Performance

Looking at historical trends, it can be said that the sector performance has improved comparatively with regard to energy use per unit space in the last five decades. However, the building sector in the Nordic markets has been criticised for not achieving its promised potential. A substantial part of the gains in energy performance has been attributed to efficiency gains in purchased energy as opposed to gains from improvements in building energy performance. This criticism is levied with the recognition that the sector has been subjected to a variety of governmental and municipal support measures and policies to improve energy performance of buildings, and the presence of many successful demonstration projects of cost effective energy efficient buildings in all Nordic markets. Then the question is why we do not see greater adoption of energy saving solutions? Has the focus of intervention been misplaced?

In the following section we examine relatively successful cases of energy saving techniques and their introduction in the Nordic markets. After presenting the cases, we focus our analysis on the dynamics of interactions of the innovating firms and their strategies in light of the innovation system in buildings.

4. Cases of energy saving techniques

The types of possible energy efficiency measures range from common sense solutions based on traditional knowledge to extensive high-tech computerized systems. In one sense, it is possible to speak of two disparate directions:

- Passive houses, simple robust systems
- Smart or intelligent houses with ICT based applications

Passive houses have exceptionally low heating requirements, in which a variety of energy efficiency promoting solutions are integrated. They are very well insulated, air leakage is kept at a minimum and mechanical ventilation systems ensure the recycling of heat. At the other end of the spectrum, energy-efficient heating and cooling of buildings can also be promoted through the use of automated controls, ventilation and improved duct systems and technologies such as setback thermostats and intelligent building controls.

An array of different technologies, technical solutions and products can be combined in a number of various ways and adapted to the location, environment and requirements of specific buildings and building projects. Thus it is not possible to identify one specific technology or approach that provides the solution to improved energy efficiency. It should also be emphasized, that energy efficiency can be attained by various means and that it is possible to combine a set of materials or products with improved properties in a manner that leads to increased energy use, similarly it is possible to combine conventional materials in a way as to provide increased efficiency. Consequently, energy efficiency in the built environment is related both to products or building materials and also to the building process i.e. how products and building materials are combined.

In the cases selection for this project, we focused on upstream changes in the building value chain, and how these changes make their way into the dominant construction and building practices. Hence we avoided an emphasis on for example passive (climatic) designs as an approach to energy savings. Although important and relevant for the discussion on energy efficiency in buildings and much can be learned from and transferred to the mainstream construction practices, passive design techniques for the time being will be considered as a niche practice with unique location factors dictating much of the opportunities for energy saving potentials. We also avoided innovations in delivered energy or conversions to renewable sources as means of energy supply, although represents an interesting potential for Nordic clean technology sector. The dynamics affecting delivered energy are substantially different with greater scope for successful institutional interventions. Substantial efficiency gains have been made in the delivered energy to buildings in many Nordic markets, for example through convention from home boilers to district heating systems, though with controversial impacts on the overall energy efficiency behaviour of individual users. Interesting and promising cleaner technology markets, both regional and export, are evolving from Nordic competencies in this area such as heat-pump technologies, solar thermal heating and cooling systems, bio-energy based heating, and PV related technologies. Again, all of these falls under a discussion of energy supply and relatively well studies by others in the field.

Finally we avoided whole building concepts. All Nordic countries experimented with demonstration buildings/projects of improved whole building concepts and we interviewed several actors involved in some of these projects. However, they represent a particular situation in which the developer/owner clearly identifies energy performance targets to be achieved by all the involved actors. These cases show that once energy performance targets are core objectives, the ability of different actors to innovate and deliver can be demonstrated once an owner exists for the energy efficiency/greening concept. However much of the learning as previously mentioned remains project specific and we do not see greater diffusion into the main stream construction industry. Perhaps also relevant in this context and for our discussion about the creation of green markets is to ask here how much of the learning/knowledge created in these projects have been transformed into core features of building offer to customers.

The cases presented here are from three product categories in the building system where energy saving potential is a core feature or part of bundle of features in the delivered value to clients. These are building insulations, Indoor climate control systems, and building automation systems. The innovations discussed in these cases are all developed in the Nordic markets, however some of the companies behind these innovations are currently part of non-Nordic based corporations. The types of innovations explored cover both incremental improvements to an exiting product as well as the introduction of a new product system, hence in line with our objective to explore a variety of dynamics in the innovation process of the case companies and the influences of institutional signals. In the following sections, we provide summaries of the changes in product/product system without direct reference to the commercial names of the case companies (based on request of some of the informants). In the analysis section we discuss the dynamics behind these changes including the influencing factors on the innovation strategies of these firms. In particular we focus on the interactions influencing the diffusion and adoption of these changes in the building innovation system.

4.1 Building Insulation

In buildings, end energy demand for heating and cooling can be reduced through improvements to the insulating capacity of wall materials, reducing losses due to thermal bridges and/or by optimizing radiation flows in wall materials. Use of thermal insulations as a sandwiched layer in wall and roof structures is considered to be one of the most commonly used methods for minimizing heat (cool) loss hence reducing end energy demand for heating/cooling. However, the effectiveness of insulating materials depends on a host of so many other factors including the size of windows, air tightness, and thickness of insulating element including proper application. In Nordic markets one can find a host of different materials for this purpose including mineral based, petroleum based and cellulose based materials. Interest in the use of insulation by home builders was notes as far back as the 1930s. However the widespread use of insulation materials in buildings remained limited in Nordic markets until it was made a legal required in Denmark in 1961, and almost 20 years later, in Sweden, with the introduction of the building code of 1978. Also the energy crisis of the 1973 pointed to the need for energy saving also in the building sector. In this respect some of the achievements in the overall energy efficiency improvements in the Swedish and Danish building stocks are attributed to these requirements.

Since then, the dominant approach to insulation remained unchanged. Innovations in insulation material segment remained limited to material substitution among the three base materials (mineral, cellulose and petroleum) or to incremental improvements in the product performance. However once the concept of insulation is integrated into the overall building envelope system, a greater scope of ideas emerge for product changes. One such example is the prefabrication of complete wall, foundation or roof systems with build-in insulation elements. The added value in such integration includes better air tightness, better control over thermal bridges and reduced time for installation onsite.

Our case company in Denmark (DK1) introduced such system for building foundations on the Danish market. The product integrates foundation’s structural requirements with insulation as one complete solution. A newer version of the product was developed in anticipation of changes to the legal requirements affecting insulations for building foundations, introduced in January 2006. The new product is promoted on a bundle of features including, light building foundation system, easy to handle, saves time, solves the insulations needs and lives up to the new insulation criteria. A similar solution was also found on the Swedish market. The product currently sells well, despite expressed views that developers and end users often do not prioritize energy efficiency in their choices of building materials. Another trend towards industrializations among construction contractors seems to benefit them.

The decision to use the product in the end building is to a large extent in the hand of construction companies and their consultants. However, the entry to market strategy of the company is explained to be through legitimizing the concept through certifications and standards, and channelling it through building materials retailers. The other options could have been to co-operate and sell directly to specific construction companies; however this was feared to lock them out of the retailers' channels which apparently play an important role for independent construction companies in Denmark. Additionally, some of the difficulties noted by the company during the process of development and launch relates to complying with other types of regulations in the building sector such as fire safety standards, and the difficulties to influence building traditions.

4.2 Indoor Climate Control Systems and Energy Recovery

Energy saving opportunities has also been exploited in the indoor climate systems of buildings. Traditionally most buildings have been fitted with passive ventilation systems. Mechanical indoor climate systems emerged as a necessity of increased insulation, air tightness of buildings and the need to ventilate to maintain a healthy indoor climate. Ventilation then became a legal requirement in all Nordic markets for most public and commercial buildings, which essentially created the market for mechanical ventilation systems. However, with the proliferation of these systems, heat losses became an issue in circulated air. Heat recovery from air has been one of the key efficiency improvements to the mechanical systems. This is achieved through installation of heat exchangers and sensors in the air handling units. Hence energy recovery became a feature of the overall functional requirements in mechanical ventilation systems. In this area we looked at two cases of system modifications that have emerged in the Swedish market. In both cases, the companies involved have also been successful in commercializing their systems in international markets.

The first case (SW1) represents modifications made in the delivery and installation of mechanical ventilation systems. The company offers a range of complementary products such as air distribution components, air treatment components, heat recovery components and control functions. Traditionally, ventilation system's design is carried out on a project by project basis. Ventilation solutions needed to be custom designed for each project. The case company opted for a modular system solution by offering several modular components that can be plugged into complete solutions for different types of buildings. Sub-components in the system are standardized and manufacturing is automated. Customers can choose from a range of standard components however with limited number of options. The energy saving potential is promoted within a bundle of features in the system including energy saving fans, efficient heat recovery and full control of temperatures. The control units are equipped with additional functions that allows for further energy saving options. Saving on space and reliability of readings are also seen as important parameters for the system's selling proposition.

In this case, the innovation strategy of the firm can be said to be entirely driven by the need to optimize and improve the process of design, delivery and installation of mechanical ventilation system. Furthermore, the company positions the product based on quality and reliability and not lowest costs. Hence, the company has been keen to emphasize internal development and research capabilities and be active in spreading knowledge, educational materials and training to various actors in the building sector. The case also provides interesting insights into the need for bundling of energy saving potential with other aspect of product innovation that is important for end users.

The second case (SW2) represents a more radical modification to the concept of indoor climate control and heat recovery in contrast with the incremental improvements in the mechanical ventilation systems. The product in this case which was launched on the Nordic market as far back as the late 70s, offers a radically different approach to indoor climate control through using the thermal mass of envelope and structural materials. The product concept is in one sense a discovery at the intersection of two knowledge areas; ventilation and concrete. The product concept makes use of the thermal retention capacity of cement in modulating the heating and cooling of buildings. Hence it is offered as an integrated solution for heating, ventilation and air conditioning at lower costs and lower end energy use than competing alternatives by use of the heat capacity of the concrete. However, it is required that it is integrated into the structural framework of the building. To market the concept, a complementary innovation was needed in the form of a measurement system to provide accurate calculations for the design of the system.

The company behind the concept made limited commercialization of the product concept both in Nordic markets and internationally. In 1977, the first building was erected using the concept. Since then, the concept has been installed in more than 200 building projects. The knowledge gained from these projects has been so favourable that an energy saving guarantee is offered in certain European markets.

The innovation strategy of the commercializing firm made use of the complementary measurement tools to help demonstrate the cost saving potentials to overcome scepticism and resistance from building owners and ventilation consultants. Energy saving potential and reduced costs for the ventilation requirements was at the core of the product offer. Also to maintain a degree of flexibility, the system was offered in combination with mechanical ventilation systems. In this respect, advantages in terms of reducing the sizing and the need for mechanical installations such as fan coils, cooling roofs, refrigerating machines, water accumulators and radiators systems, all were important selling arguments.

The success of (SW2) product depended to a large extent on the early integration in the design phase of building project. This meant that the mechanical engineering consultants needed to be in contact with (SW2) sales staff in the early phase of calculating and dimensioning of the heat/cool requirements. Developers and architects also needed to make certain adjustments in construction techniques including changes to some of the established approaches in roof construction.

4.3 Building Automation Systems

Another level where energy savings can be achieved is through optimizing the control and performance of building sub-systems such as heating and cooling, ventilation, lighting and appliances in an integrated fashion. By connecting various energy consuming devices to intelligent software system, optimization opportunities for reducing end energy demand exist up to 30%. The integration allows the overall energy system to work together seamlessly and to be controlled according to needs and situations. These systems have been in the market from the 80s and were mainly used in commercial and high rise buildings. However, their application in the residential home segment has been limited. Our case companies in this area are both based in Finland and their product builds on a concept that was initially developed through a national technology program called Connected Open Building Automation (COBA) and later commercialized for residential applications. What COBA offers is a common interface to all facility management systems: heating, cooling, ventilation, lighting, metering, access and attendance, surveillance as well as burglar, fire and humidity alarms. Commercial COBA based products emerged in the market in 2003.

Two companies made attempt to commercialize COBA-based products, with mixed level of success. The first case company (FI1) has been involved in the software development for COBA. The other company (FI2) provided the control modules that interface with various subsystems. FI1 managed to commercialize close to 100 systems before going out of business due to financial reasons. FI2 has been more successful in commercializing its products and currently active in export markets such as Norway, Russia and United Arab Emirates.

In the development phase, both companies benefited substantially from the resources provided by the COBA consortium partners. Since COBA started as a standardization project it managed to attract key actors in complementary knowledge basis such as telecommunications, software development, control devices and building service providers (COBA-group.com). In this case the project focus in interface standards seems to be necessary for the innovation environment for these companies.

During the marketing phase, both companies needed to create alliances with ventilation machine producers, heating machine producers, security companies, resellers, engineers and architects. However, the more successful company (FI2) in the commercialization stage attributes the break through to the choices made regarding the product interface standards. By allowing users open access to build interfaces with the product, they could attract supplier to the system and with it their customers.

5. Analysis and Discussion

5.1 Constraining conditions and innovation strategies of the firms

The sectoral features of the building industry as discussed create constraining environment for innovation. Previously we outlined some of these constraining conditions, mainly in the allocation of risks and incentives and in the learning and transfer of knowledge. In examining the innovation strategies of the case firms, we can identify several measures that seem to have been effective for the case companies.

The first pattern is seen in attempts to simplify or legitimize the information flow to the different actors influencing the adoption process. Also important to point out that demonstrating the potential for energy saving was not often central in these information exchanges. For instance, several of the case companies focused on product certification and accreditations to show compliance with regulatory demands and standards. DK1 was keen to demonstrate how their new system helps clients to comply with the new requirements, and demonstrated that with certifications and accreditation process with supposedly legitimate actors such as universities. In the Finnish cases, the more successful of the case companies was the one with an open protocol “horizontal strategy” allowing a verity of suppliers to plug in and communicate with their system.

The second pattern is seen in terms of creating complementary and credible information channels such as measurement and calculation tools, performance modelling tools or professional training. SW2 software invention was essential in communicating with consultants, engineers and architects about the new concept, and for convincing owners and developers of the benefits. SW1 strategy focused on sustained technical training programs and seminars to different actors in the value-chain. SW1 also addressed the general scepticism about mechanical ventilation among final users by bundling the reliability of measurements and readings into the value offer to end users.

Open standards, product certifications, and complementary communication aids played an important role in lubricating the flow of information, creating legitimacy to new modification; however the perception of risks from new experimentation on-site remained a challenging one. Case companies’ use of demonstration projects (FI1, SW1, SW2) and performance guarantees (SW1) seem to have addressed the scepticism about the technology itself and created a cycle of learning about the integration at the project level. Transfer of project level learning to familiar routines among the actors network, remains a risky business that deters form wide adoption. A focus on simplicity, ease of installations complemented with stable alliances (DK1), training (SW1), and open source (FI1), evident from the case companies, seem to have played a role in this respect.

What is also evident from the companies' strategies is to bundle a variety of benefits which seems to have worked well in addressing the problem of incentives, allowing actors that can have an influence on the procurement decision to appropriate their own benefits along the way. Although we may see an energy saving goal in the commercialization of these products and systems, the selling propositions focuses on satisfying a host of many other incentives in the value chain, including helping clients meet regulations (DK1), project level cost savings in terms of shorter time (DK1, SW1), ease of connectivity by other suppliers (FI1, SW2), reliability for end users (SW1, SW2), and more space for architects to play with (SW1, SW2) are just some of the bundled features found in the case innovations.

5.2 Constraining Conditions and Innovation Activities

In the previous analysis we explored how innovative firms operate in relation to specific constraining features of the construction sector which tends to create a challenging environment for the diffusion of innovation. A first general observation is that contrary to generalised opinions about weak innovative capacities in building sector, the conditions in Nordic markets provide a slightly different picture. The question is not an issue on the rate of invention but on the rate of diffusion. The following observations from the case materials provide more nuances to some of the enabling and constraining conditions in three activities of the building innovation system: access to knowledge, access to resources and market formation.

In the area of knowledge and looking specifically at certain divisions in the Nordic building sector such as materials suppliers, building services systems producers, engineers, designers there is a high degree of "adsorptive capacity" with regard to identification and utilization of new knowledge that is important for innovation. A credit perhaps to some of the features found in Nordic innovation systems such as strong knowledge base in complementary areas of material sciences, mechanical engineering, design and electronics coupled with highly trained labour force in most segments of the industry. To illustrate, some of the knowledge input identified in the cases come from interfaces with other sectors such packaging, information technologies and mechanical engineering.

On the other hand weak relationships with formal knowledge institutions such as research centres and universities have been sited on several occasions. However, this has not materialized strongly in the case materials. In one occasion, the core knowledge for the innovating firm was developed in academia. In two other occasions the innovating firms established connections with formal knowledge organizations for creating legitimacy and acceptance for the alternative technique.

Another fundamental weakness is the decoupling of energy efficiency related knowledge for the building sector from the traditional training of designers, engineers and consultants. Although one could find specialized courses on climatic design, passive buildings, alternative heating and cooling technologies as examples, these tend to remain outside the traditional specializations accessible to building sector.

In the provision of resources, the sector faces several issues. On the human resources side, the sector is facing an ageing skilled labour force coupled with a weak interest from younger generations. However, this issue seems to have been noted by educational policy makers in some of the Nordic markets in particular Sweden where new programs have been launched to make it attractive for young graduates to enter into this sector. The cyclical nature of the building market in Nordic countries seems to have also impacted investments in development activities. The upswings and downswings is said to have an effect on the industry’s access to financial and human resources, acting as a barrier to investment in research activities.

Finally with regards to *market formation*, in most Nordic markets building codes have been sited as the most influential instruments for creating the demand for energy efficiency in buildings. This has been limited to certain areas of applications, mainly insulations and heat recovery. This and a historic emphasis on technical specifications (u-values of wall materials) rather than performance specifications (end energy demand per functional units) led to incremental improvements rather than radical changes. The split-incentives in energy investments (one party pays for the investments and another party pays for the energy bill) has also been noted as a barrier to market development, though not unique to Nordic markets and pervasive across the sector internationally. There could have been an opportunity to overcome this split-incentive problem in the Nordic market with the historical role of municipal housing firms to steer the market differently considering the “public good” nature of their work.

6. Conclusions and Policy Implications

Overall the knowledge base and the socio-political debate in Nordic markets can be characterized as mature in terms of creating the conditions for an “ecological modernization” of the sector where there is political and social acceptance for more sustainable practices. Our key point is that the challenges of energy efficiency diffusion in the Nordic building markets are found more in the general features of construction industry and the organization of the building sector.

Our analysis of the innovation strategies of the case firms and the enabling conditions in Nordic markets raises several discussion points for the broader debate on energy efficiency and buildings. The first one concerns actors’ strategies. Innovators in the area of energy efficiency need to go beyond the goal of just optimising the energy dimension in the value offer. Nearly all the case firms offered a bundle of features in the value proposition satisfying different needs of different actors in the building value chain. Clearly illustrated by the cases, successful commercialization involves directly confronting the structural features in the industry that are affecting adoption decision. Since many actors with different interests and frames of reference influence the adoption process; the flow of information and the distribution of incentives can have direct influence on the successful commercialization. This is of course mostly relevant in the absence of clear energy efficiency procurement requirements.

The second point concerns public policy. Despite the fact that we can identify many possible ways of boosting energy efficiency in buildings, adoption at the project level is complicated by systematic and structural features in the building innovation system. This has direct implications on polices aimed at achieving transformation towards a more energy efficient building stock. Policies need to be sensitive to specific features of the dynamics of interactions in sector and national contexts. The case materials highlight some of these opportunities for intervention. This is best amplified by the Finnish cases where the innovating firms benefited greatly from the publicly funded technology program on open standards allowing a variety of actors to integrate their products and systems through an open protocol.

The ‘popular’ tool box of tax incentives and subsidies for energy efficiency measures has proven to be of limited success. These tend to create temporary markets for particular products or services. An emphasis is needed more on: 1) reducing the uncertainty associated with experimentation from project level adoption 2) facilitating learning, knowledge transfer and information flows in a sector characterised by a fragmented knowledge base. Furthermore, the potential for advancing an energy-performance based market for buildings is still in its early phases. There seems to be optimism in the industry around performance certification schemes in line with recent EU directive offers the promise of a stronger market demand for energy efficienct buildings.

7. References

Beerepoot, M. 2007, “Public energy performance policy and the effect on diffusion of solar thermal systems in buildings: A Dutch experience.” Renewable Energy 32(11): 1882–1897.

Biggart, L. and Lutzenhister, N. 2007, Economic Sociology and the Social Problem of Energy Inefficiency, American Behavioral Scientist, Vol. 50 No. 8, 1070–1087.

Bröchner, J. 2006, “Manufacturing or services innovation? A survey of Swedish construction contractors”. Presented at RIDE Seminar. 21 April 2006. Chalmers University of Technology, Göteborg, Sweden.

Brown, M. A., F. Southworth, et al. 2005, Towards a Climate Friendly Built Environment: Report Prepared for the Pew Center on Climate Change. Oak Ridge National Labratory.

Chaminade C, Edquist C (2006). From Theory to Practice: The Use of the Systems of Innovation Approach in Innovation Policy. In J Hage, M Meeus (eds) Innovation, Science and Institutional Change: A Research Handbook. Oxford University Press: New York, p. 141–160.

Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.
OJ L 1, 4.1.2003, p. 65–71.

European Commission COM (2005) 265, Doing more with less. Green Paper on Energy Efficiency.

Edquist, C. (ed.) 1997, Systems of Innovation, Frances Printer: London.

Enova 2007, Retrieved 19 September 2007 from http://www.enova.no/?itemid=79

European Commission 2003, Better Buildings – New European Legislation to Save Energy: Information Leaflet.

Gann, D. and Salter, A. 2000, Innovation in project-based, service-enhanced firms: The construction of complex products and systems, Research Policy, Vol. 29, 955–972.

Goverse, T., Hekkert, M.P., Worrell, E., Smits, R. 2001, Wood innovation in the residential construction sector: opportunities and constraints, Resources, Conservation and Recycling, Vol. 34, 53–74.

Ingvaldsen, T., A. Lakka, et al. 2004, Productivity studies in Nordic building and construction industry. Norwegian Research Building Institute. Project report 377 − 2004

Jacobsson, S. and Bergek, A. 2004, Transforming the energy sector: the evolution of technological systems in renewable energy technology. Industrial and Corporate Change, Vol. 13(5): 815–849.

Jansen, R. 2004, Towards energy efficient buildings in Europe. Final Report. The European Alliance of Companies for Energy Efficiency in Buildings.

Kemp, R. 1997, Environmental Policy and Technical Change: A Comparison of the Technological Impact of Policy Instruments. Edward Elgar: Cheltenham, UK.

Kristiansen, K., S. Emmitt, et al. 2005, “Changes in the Danish construction sector: the need for a new focus.” Engineering, Construction and Architectural Management 12(5): 502–511.

Malerba, F. 2005, Sectoral Systems of Innovations: A framework for linking innovation to the knowledge base, structure and dynamics of sectors, Econ. Innov. New Techn., Vol. 14, No. 1–2, 63–82.

OECD 1997, National Innovation Systems, OECD: Paris.

Reichstein, T., A. Salter, et al. 2005, Last among equals: a comparison of innovation in construction, services and manufacturing in the UK, Construction Management and Economics, Vol. 23, 631–644.

Rockwool 2007, “Energy Efficient Buildings”. Presented at Sino-Danish Forum on Renewable Energy and Energy Efficiency. 11–14 May 2007. Copenhagen, Denmark.

Rozite, V. 2006, Innovation in the building sector – promoting energy efficiency in Sweden and Denmark. MSc. Environmental Management and Policy Thesis. International Institute for Industrial Environmental Economics, Lund University.

Sector Workshop 2007, Eenrgy Efficiency of the Building Sector: workshop of the GMCT project: Nordic Innovation Center, Oslo, 13 March 2007.

Shove, E. 1998, Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings, Energy Policy, Vol. 26, No. 15, 1105–1112.

Smeds, J. 2004, Energy Aspects in Swedish Building Legislation of the 20th Century Concerning Dwellings. Lund Institute of Technology. Lund, Sweden.

Taylor, J. and Levitt, R. 2005, Inter-organizational Knowledge Flow and Innovation Diffusion in Project-based Industries, Proceedings of the 38th Hamaii Conference on System Sciences.

UNEP 2007, Buildings and Climate Change: Status, Challenges and Opportunities. United Nations Environmental Programme.

Virtual Finland 2004, “Finnish industry today after major changes.” Retrieved 30 July 2007 from http://virtual.finland.fi/netcomm/news/showarticle.asp?intNWSAID=28308

Widen, K. 2002, Innovation in the Construction Process, Licentiate Thesis, Division of Construction Management, Lund Institute of Technology: Lund.

8. Sammanfattning på svenska

I följande rapport sammanfattar vi resultaten från undersökningen av exempel på energieffektivitetsinnovationer i den nordiska byggsektorn som en del av projektet "Green Markets and Cleaner Technologies (GMCT)". GMCT-projektet har finansierats av Nordiska Ministerrådets tvärsektoriella arbetsgrupp för integrerad produktpolitik (NMRIPP) och genomfördes i samarbete mellan Internationella Institutet för Industriell Miljöekonomi (IIIEE) vid Lunds universitet, Miljöforskningscentralen i Finland och Avdelning för Samhällsutveckling och planering vid Aalborgs universitet.

Syftet med denna branschstudie är att ge empiriskt underlag till GMCT-projektet om de process- och systemförutsättningar som underlättar eller motverkar miljöinnovation i ett branschsammanhang, i detta fall byggindustrins speciella förhållanden. Den baseras på litteraturgenomgång, två magisteruppsatser som genomförts inom ramen för detta projekt, intervjuer, diskussioner från en workshop samt kommentarer från representanter från den nordiska byggindustrin. De undersökta fallen kommer i huvudsak från material- och komponenttillverkare i den övre delen (uppström) av byggsektorns värdekedja. De omfattar fall på gradvisa förbättringar av befintliga produkter till nya produkter och produktsystem.

Genomgången som genomförts i denna rapport berör det branschspecifika sammanhanget och uppmärksammar flera av byggindustrins viktiga karaktärsdrag som har betydande följder för dess innovationsmiljö. Det mest betydande draget är sektorns projektbaserade natur och att införlivandet av innovationer sker i projekt och inte i själva företagen som sådana. Den andra aspekten av denna innovationsmiljö är det stora antalet aktörer som är engagerade i beslutsprocessen, där en aktörs handlingar ytterst påverkar nästa aktörs handlingar. På så sätt är produktionen av en mer energieffektiv byggnad resultatet av komplexa och kombinerade ansträngningar från en hel rad aktörer. Det räcker inte bara med att ägaren till byggprojektet är beredd att finansiera den energieffektiva byggnaden; byggnaden och dess olika system måste både ges en lämplig utformning av arkitekter och ingenjörer och de människor som behövs för att genomföra byggandet måste ha den rätta yrkesskickligheten. Vidare är aspekter som sektioneringen och uppdelningen av byggnadens värdekedja, byggprojektetens medverkande aktörers olika förmåga till kunskapsintegration samt branschens cykliska natur, vilken påverkar investeringar i ny kunskap, också mycket betydande drag för denna bransch.

Dessa karaktärsdrag för byggarbetena, dock inte unika för den nordiska marknaden, skapar en begränsande miljö för innovationer i allmänhet och för energieffektiva lösningar i synnerhet. Exempelvis kan kunskaper som har vunnits genom samverkan och läroprocesser i ett byggprojekt vara svåra att fånga och/eller föra vidare till framtida projekt. Olika kombinationer av aktörer kan arbeta ihop i olika projekt, vilket medför svårigheter med att samla erfarenheterna. Eftersom de medverkande aktörerna har varierande bakgrunder kan vidare deras erfarenheter till stor del vara förbehållna för det område de är specialiserade inom. Under dessa givna betingelser, hur tar sig framgångsrika energiinnovationer till den breda marknaden? Och vilka insikter kan vi få från aktörernas innovationsbeteende i verkliga fall? Dessa är några av de frågeställningar vi försökt undersöka genom att se på specifika fall från de nordiska byggmarknaderna.

Resultat från fallstudierna visar att innovationsföretagen använder sig av flera olika strategier för att komma förbi de begränsningar som beskrivits ovan. Beträffande fallet att föra samman aktörer har öppna standarder, produktcertifiering samt kompletterande kommunikationsverktyg spelat en viktig roll för att underlätta informationsflödet och skapa legitimitet för nya modifikationer. Fallföretagens användning av demonstrationsprojekt och garantier för prestanda verkar ha använts mot osäkerheter om innovationen som sådan och skapat en lärandecykel om integration på projektnivå. Att överföra lärande på projektnivå till invanda rutiner i aktörsnätverken kvarstår som en riskfylld verksamhet som försvårar en större spridning. Vi ser från fallföretagen att budskap med fokus på enkelhet och underlättade installationer tillsammans med stabila allianser, utbildning och förenklad aktörssamverkan verkar ha spelat en roll för att minska riskuppfattningen.

Därefter undersökte vi även underlättande och begränsande förhållanden för ett innovationssystems tre aktiviteter (tillgång till kunskap, tillgång till resurser och skapande av marknader) samt hur dessa förhållanden påverkar utvecklingen av innovationer inom energieffektivitet.

Inom områdettillgång till kunskap, och då speciellt genom att se på uppströms aktörer såsom materialleverantörer, byggsystemproducenter, ingenjörer och arkitekter finns en hög grad av ”upptagningskapacitet” med hänsyn till att identifiera och använda ny kunskap nödvändig för innovation. Detta gäller kanske speciellt för några av de karaktärsdrag vi funnit i nordiska innovationssystem såsom en stark kunskapsbas inom de närliggande områdena materialvetenskap, mekanisk industri, design och konstruktion samt elektronik tillsammans med en högt utbildad arbetskraft i de flesta av branschens delar. De svagt utvecklade relationerna till externa kompetenscentra såsom forskningsinstitut och universitet har, å andra sidan, nämnts vid flera tillfällen. En ytterligare fundamental svaghet är bristen på undervisning i energieffektivitet i de traditionella utbildningarna för arkitekter, konstruktörer, ingenjörer och konsulter. Även om man kan hitta speciella kurser i t.ex. klimatdesign, passiva hus, alternativa uppvärmnings- och kylningstekniker tenderar de att förbli utanför de traditionella specialiseringarna tillgängliga för byggsektorn.

Inom tillgång till resurser möter byggsektorn flera frågeställningar. De förfaller att påverka innovationer i allmänhet och inte speciellt inom energieffektivitet. Humankapitalet inom sektorn är en åldrande yrkesskicklig arbetskraft samtidigt med ett bristande intresset från yngre generationer att ta vid. Denna fråga verkar emellertid ha noterats av beslutsfattare inom utbildningspolitiken i några av de nordiska marknaderna, särskilt i Sverige där nya program har lanserats för att göra det mer attraktivt för unga utbildade personer att komma in i denna sektor. Byggmarknadens cykliska natur i de nordiska länderna verkar också ha påverkat investeringarna i utvecklingsaktiviteter. Upp- och nedgångarna sägs ha en effekt på industrins tillgång till både finansiellt kapital och humankapital, vilket fungerar som ett hinder för investeringar i forsknings- och utvecklingsaktiviteter.

Om vi slutligen ser på *skapandet av marknader* sägs byggnormer vara det viktigaste instrumentet för att skapa efterfrågan på energieffektivitet i byggnader i flertalet nordiska länder. Effekten har emellertid varit begränsad till enskilda tillämpningsområden t.ex. isolering och värmeåtervinning. Detta tillsammans med en historisk tyngdpunkt på tekniska specifikationer (slutligt energibehov per funktionell enhet) medförde glidande förbättringar snarare är drastiska förändringar. De delade incitamenten för energiinvesteringar (en part betalar för investeringen och en annan betalar energiräkningen) har också beskrivits som en marknadsbarriär men som inte är unik för den nordiska marknaden utan gäller för branschen internationellt. Det kunde ha funnits en möjlighet att komma förbi frågan om dessa delade incitament för den nordiska marknaden med den starka roll som allmännyttiga bostadsbolag har för att styra marknaden på ett annat sätt beaktande uppgiften att skapa just allmännytta genom sitt arbete.

Beträffande rollen för allmänna policy-initiativ finns det ett behov av hög känslighet för de speciella karaktärsdrag som ligger i dynamiken i branschens samverkan. Trots att vi kan identifiera flera möjliga utvecklingsvägar för att främja byggnaders energieffektivitet försvåras acceptansen på projektnivå genom systematiska och strukturella egenskaper i byggsektorns innovationssystem. Dessa har direkta följder för policies syftande till att uppnå en omvandling mot ett mer energieffektivt byggbestånd. I detta sammanhang har den vanligtvis använda verktygslådan bestående av skattemässiga incitament och stöd för energieffektiviseringsåtgärder visat sig ge begränsad framgång. Vi drar därför slutsatsen att åtgärder som aktivt minskar osäkerheterna i samband med experimenterande med acceptans på projektnivå, underlättar lärandet, kunskaps- och informationsflödet ges större tyngd i en bransch som karakteriseras av en fragmenterad kunskapsbas.

Appendices

Appendix 1: Final Program for the sector workshop on energy efficiency in buildings

The sector workshop on energy efficiency in building is held as part of the Greem Markets and Clean Technologies (GMCT) project. The workshop aim is to discuss and provide input into the findings from the case studies of this report.

The workshop was held on the 13th of March 2007, in Oslo, Norway. It was generously hosted by the Nordic Innovation Centre (NIC).

Opening the Workshop

9.30 – 9.45	**Introduction of the project and participants, Åke Thidell, IIIEE**
9.45 – 10.00	**Introduction of Nordic Innovation Centre, Sigridur Thormodsdottir, NIC**
10.00 – 10.30	**Current and future innovation in the building industry, Svend Svendsen, DTU**

Session 1: Innovation Case Studies – findings and discussion

10.30 – 11.30	**Innovation in the building sector: cases from the Nordic countries. Presentation of preliminary findings. Åke Thidell, Tareq Emtairah and Naoko Tojo, IIIEE**
11.30 – 12.00	**Drivers and barriers to innovation in energy efficiency, Lena Neij, IIIEE**
12.00 – 13.00	**LUNCH (at Nordic Innovation Center)**

Session 2: Industry's view on improving innovation potentials in energy efficiency of building

13.00 – 13.25	**Integrated energy design for energy efficient buildings, Fritjof Salvesen, KanEnergi AS**
13.25 – 13.50	**Launching an innovative product on the market: experiences and challenges, Arne Hellström, Strängbetong**
13.50 – 14.15	**Industry initiatives and cooperation among sector actors, Per Lilliehorn, Eco-cycle Council**

Session 3: Group discussions and synthesis

14.30 – 14.45	**Introduction to group discussions, Naoko Tojo, IIIEE. Group discussions will focus on three prerequisite for innovation – access to knowledge, access to resources and the formation to markets.**
14.45 – 16.15	**Group 1: access to knowledge and resources**
	Group 2: access to market
16.15 – 17.00	**Synthesis of group discussions and final words, IIIEE**

Appendix 2: Participants of the policy workshop

Arne Hellström, Strängbetong AB
Britt-Marie Jansson, Sveriges Arkitekters Miljögrupp
Fritjof Salvesen, KanEnergi
Kajsa Sundberg, Samverkansforum för statliga byggherrar och förvaltare
Karin Ibenholt, ECON AS
Lena Neij, IIIEE, University of Lund
Helene Axelsson, Swedish Energy Agency
Ottar Madslien, GRIP, for bærekraftig produksjon og forbruk
Ove Mørk, Cenergia Energy Consultants
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